DESIGN AND DEVELOPMENT OF A HOT PRESS MACHINE FOR COMPOSITE MATERIAL FABRICATION APPLICATION

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DECLARATION

I declare that the work in this project, titled "Design and Development of a Hot Press Machine for Composite Material Fabrication Application" has been carried out by me with assist from my supervisor Dr Choong Wai Heng in the Faculty of Engineering Universiti Malaysia Sabah. The information derived from the literature has been duly acknowledged in the test and a list of references provided.

1st July 2022

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It is a great opportunity and achievement for me to complete my Final Year Project entitled Design and Development of a Hot Press Machine for Composite Material Fabrication Application. First and foremost, praise and thank the God, the Almighty, for His showers of blessing throughout the completion process of the project. I want to express my gratitude to Universiti Malaysia Sabah (UMS) especially Faculty of Engineering for the guidance that I received to enhance my skills in the Mechanical Engineering. In general, this project was intended to use information gained in the Mechanical in Engineering program as well as to fulfil the requirement of the Final Year Project course, which leads to a Bachelor of Mechanical Engineering with Honours Degree.

Next, I would want to specifically thank Dr. Choong Wai Heng as my Final Year Project supervisor. All the ongoing assistance, effort commitment, and talent it took to construct my machine are greatly appreciated. He spent a lot of time, including the weekend, which he could have spent relaxing with his family, but instead helping me in the lab to construct my machine and assisting with the machining aspect. Thank you for all the support and keep pushing me to put more effort in this project. Not to forget other lectures of Faculty of Engineering UMS especially Mechanical Engineering Program for the support and knowledge.

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ABSTRACT

Design and development of hot press machine for composite material fabrication application is build specific for an educational purpose and study the properties of composite material based on the fabrication procedure or the ratio mixture of composite material. The development task starts with some research on causes that can affect the composite material properties in the fabrication area and machine design requirement is developed from this information. The final design for the hot press machine was developed by using CAD engineering software known as SolidWorks. Critical component of machine was analyse using both theoretical and simulation analysis using SolidWorks software to understand the deformation behaviour of this machine and finding the limitation. Thermal study analysis also run to determine the time required for the heating element to heat up the plate to set point temperature. Result of thermal study show 64 minutes is time required to heat the overall panel surface to the range of 140°C to 150°C. Machine prototype was built and tested by fabricate three panel rice husk composite material and observe thickness uniformity of each panel. A deviation of panel thickness from the reference 4.2mm panel thickness is represented by percentage error value. Panel 1,2 and 3 have maximum percentage error 46.43%, 20.48% and 3.81 % respectively. Thickness measurements are considering the tolerance geometry standard ASTM D7136. A decreasing percentage error show an improvement of composite panel fabricated using this machine. The composite panel thickness accuracy and uniformity can be achieved through the improvement strategy.

ABSTRAK

Reka bentuk dan pembangunan mesin penekan panas untuk kegunaan penghasilan bahan komposit dibina khusus untuk tujuan pendididkan dan mengkaji sifat bahan komposit berdasarkan prosedur fabrikasi atau campuran nisbah bahan komposit. Proses pembinaan mesin bermula dengan beberapa kajian mengenai punca yang boleh menjejaskan sifat bahan komposit melalui proses pembikinan dan keperluan reka bentuk mesin dibangunkan berdasarkan maklumat yang diperoleh. Reka bentuk akhir mesin penakan panas telah dibangunkan dengan menggunakan perision kejuruteraan CAD yang dikenali sebagai Solidworks. Komponen kritikal mesin dianlisis menggunakan teori dan simulasi dalam perisian SolidWorks untuk memahami perubahan bentuk mesin dan mencari takat had mesin. Analisis kajian terma juga dijalankan untuk menentukan masa yang diperlukan untuk elemen pemanas memanaskan plat kepada suhu yang ditetapkan. Hasil kajian menunjukkan 64 minit adalah masa yang diperlukan untuk memanaskan keseluruha panel pada julat suhu 140°C hingga 150°C. Prototaip mesin telah dibina dan diuji dengan menghasilkan tiga panel komposit sekam padi dan memerhatikan keseragaman ketebalan setiap panel. Perbezaan ketebalan daripada ketebalan rujukan 4.2mm ditunjukkan dengan nilai peratusan ralat. Panel 1,2 dan 3 masing-masing mempunyai peratusan ralat maksumum 46.43%, 20.48% dan 3.81%. Pengukuran ketebalan adalah mengambil kira toleransi piawain geometri ASTM D7136. Ralat peratusan yang menurun menunjukkan penambaikan panel kompsot yang direka menggunakan mesin ini. Ketepatan dan keseragamaan ketebalan panel komposit telah dicapai melaui penambaikan yang telah dilakukan.

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$F_1 = Force\ 1\ (N)$

$F_2 = Force\ 2\ (N)$

$A_1 = Area\ 1\ (m^2)$

$A_2 = Area\ 2\ (m^2)$

$MV = Manipulated\ Variable$

$P = Proportional\ Constant$

$I = Integral\ Constant$

$D = Derivative\ Constant$

$G(s) = Transfer\ Function$

$K_p = Proportional\ Gain$

$K_L = Integral\ Gain$

$K_d = Derivative\ Gain$

$T_i = Integral\ Time\ Constant$

$T_d = Derivative\ Time\ Constant$

$P = Load$

$L = Length$

$h = Height$

$m = mass$

$E = Young\ Modulus\ of\ Material$

$I = Moment\ of\ Inertia$

$C = Specific\ heat\ Capacity$

$\Delta T = Temperature\ \ Difference$

CHAPTER 1

INTRODUCTION

1.1 Overview

Composite material research, development, and manufacturing are all ongoing and evolving in our period since composite materials constitute one of the most significant and varied classes of materials. Natural fiber composite materials are in great demand because to their desired features such as low cost, renewable energy, biodegradability, and high specific properties (Muniyasamy Kalanchiam & Moorthy Chinnasamy, 2012). Hand lay-up method is a traditional and existing method of fabrication composite material that is mostly used in the industry and institutions for composite material education. Hand lay-up refers to the process of manually laying down individual layers or "plies" of a type of reinforcement known as "prepreg." This is made up of thousands of fibers that have been pre-impregnated with glue and bundled into tows before being woven together or organized in a single unidirectional ply. Each ply is hand-manipulated into form before being securely adhered to the preceding layer or mould surface, leaving no air pocket between plies (Elkington *et al.*, 2015).

This technique is advantageous because it can generate high-quality complex features at a reasonable cost. However, this approach is far from ideal, since production rates are poor, and a new method to apply pressure to a mould plate must be developed, as some people still use an external load to compress the material by simply placing it on the plate. This can have an impact on the quality of composite materials since it can result in variable thickness, incorrect material bonding if not enough pressure is applied, and a low-density material (Elkington *et al.*, 2015). Applying a hydraulic press to press the mould plate ensures constant and evenly distributed pressure on the composite panel surface, which is far superior to merely loading the plate. A hydraulic press is a mechanism that works based on Pascal's law, transferring energy via a liquid (Jan Schuren & Kay Mohr, 2020). This technology is already in use in the plywood production sector, using a machine known as the BLAZE 120. BLAZE 120 is a hydraulic hot press for pressing laminates, veneers, and chipboard onto MDF, plywood, and chipboard. It features a bottom platen that moves via hydraulic oil cylinder actuation. This machine also used thermic oil heating technology to regulate the temperature so that the plywood glue could be activated at the optimum temperature for gluing (Biesse, 2015)

Previous study on the performance of cotton-kapok fabric polyester composites produced specimens with a variation in breaking load between the center specimen and those collected from other sections of the sample due to an uneven distribution of the curing temperature during the hot compression stage (Montserrat & Málek, 1993). Epoxy resin and hardener are commonly employed in the manufacturing of composite materials such as bamboo flake composites, carbon-fiber composites, and wood composites. Temperature is one of the most essential variables in ensuring adequate cure of the epoxy resin and hardener, with the optimal cure temperature being somewhat warmer than room temperature (24°C -30°C). Resin will take longer to cure if the temperature is below 22°C, and it may stay sticky or not cure at all (Montserrat & Málek, 1993). However, depending on the composite material, this optimum temperature may vary. In the fabrication of High-Density Polyethylene (HDPE) saturated board by using a mechanical recycling method, usually a melting and pressing process is done separately

where the melting part will be done in an oven or a hot plate (Grigore, 2017). Hot press machine is required because it can do this process simultaneously to fabricated HDPE board. Hot press mechanism is also required in the fabrication of wood plastic composite and chipboard because a convenient temperature and pressure influence in the panel quality and activation of the glue. Chipboard are usually compressed between 2-3 Mpa and temperature between 140°C and 220°C. Hereby, a temperature controller is needed in press machine to control the temperature of a mould plate.

There are many different types of hot press machines on the market, but none of them are designed and developed specifically for composite material fabrication for education purpose. For example, the hot press machine model LCB1015-3 from China has a small plate size (15 cm x 20 cm) and a high price tag of RM 2400.00. Aside from that, the EQ-HP-88V-350 25T hydraulic laminated hot press machine is a high-quality equipment with water cooling for a faster plate cooling procedure. However, owing of the complex and high-quality equipment, it costs RM 37359.00 and weighs approximately 224.53 kg. Both machines are not suitable and worth buying to fabricate a composite material.

The goal of this project is to design and build a hydraulic hot press machine to produce composite materials. Because there is a dearth of machine in the production of composite panels, this project is suggested to build a low-cost machine that may be utilized in the faculty by students and lecturers for educational purposes. Instead of utilizing a manual compression, a hydraulic hot press machine for manufactured composite material is designed to make it easier to make composite panels for educational purposes. The important characteristic of this hydraulic hot press machine is needed to have a flat surface plate for mould, evenly distributed pressure and temperature throughout the plate surface and the ability of thickness control. A hydraulic jack, frame, heating element, A4 size mould, and PID controller to control plate temperature are the key components of this machine.

1.2 Problem Statement

Composite material has undergone a spectacular development because advanced composite materials can offer a range of advantages, which have made them desirable in many high-performance applications. The study, research, and fabrication of composite material in university level are often done to explore the mechanical properties of composite material. To improve the composite overall performance, it is needed not only consider the mechanical properties estimation models but also the manufacturing process with its advantages and limitation. The manufacturing process of composite material are directly influence by the stacking sequence, fiber volume fraction and morphology, as well as the cure process (Avila & Morais, 2005)

Traditional and most famous hand layup method in fabrication of composite material for high standards of quality and lower cost are most use in this industry. Research done by (Wittman & Shook, 1982) on hand lay-up techniques have an advantage on design flexibility, low tooling cost, large and complex items can be produced, and this process only need semi-skilled workers and are easily trained. Despite on the advantages this research also highlights a few disadvantages regarding this technique where only one good (moulded) surface is obtained, low-volume process and product uniformity is difficult to maintain within a single part or from one part to another. Research by (Daniel & Abot, 2000) of void formation on laminated composite by hand lay-up method where it can form either by mechanical entrapment of air or by nucleation from vapors or gases. The mechanical entrapment could be due to entrained gas bubbles from resin mixing operations, bridging from large particles, voids from wandering tows, broken fibres, or air pockets and wrinkles created during the lay-up. Void formation causes stiffness and strength reduction. He went further correlate that void formation also can be due to the time and temperature during the resin cure (Mohd Sapuan Salit *et al.*, 2015). Also in the hand lay-up process, a non-uniform pressure during the manual resin impregnation can lead to a path of fibre imperfections (Avila & Morais, 2005). For example, in the hand lay-up process of fiberglass composite fabrication where brushed

or rolled only use to compact the material and removed entrapped air (Wittman & Shook, 1982) which can cause imperfection surface and bubbles.

Design and development of this hydraulic hot press machine can be a solution to a problem for an existing fabrication technique of composite material. With the use of hydraulic jack to deliver a pressure, a specimens can be producing with the ability of thickness control and a better pressure distribution to reduce the void formation in the composite material which also can be caused by a trapped air bubble during the treatment. Equal pressure distribution is measure by divided the composite panel into several section and measure the average thickness of each section. This will be the main problem to be solved in this project. By a reference composite panel, the accuracy of this machine will be measure with the ability to fabricate a composite panel with a same thickness as the reference panel. By using the standard geometry of material as thickness reference, the accuracy of this machine will be measured with the ability to produce numbers of material with a constant thickness. A statistical analysis research was conducted on the hand lay-up manufacturing process with cure to air, cure under compression, and cure with vacuum assistance show that cure under compression result in a smaller void sizes and higher fiber volume fraction of 49.03% which led to a better mechanical property (Avila & Morais, 2005). Temperature control is also introduced in the machine to help in providing an ideal curing temperature for the material, melting process and optimum temperature for glue activation, and hardening. Machines are design to fabricate a composite panel with size 290mm x 170mm as this machine are used to fabricate a composite material more toward to education, demonstration, and research application.

1.3 Research Objectives

The main objective of this project is to design and develop a hydraulic hot press machine for composite material fabrication application by using a hydraulic jack, heating element

and PID temperature controller. The project main objectives can be further specified into 4 specific objectives as following:

i. To design a virtual 3D model of hydraulic hot press machine for composite material fabrication application.
ii. To determine the virtual hydraulic hot press machine system performance.
iii. To prototype the physical hydraulic hot press machine.
iv. To validate the machine performance

1.4 Scope of Works

Scope of work is a research project work that contains the areas to be covered by this project and should be approached with the clearest term because it can determine whether the aims of the project have been achieved. The following scope of work are the steps follow to achieve this design and development of hydraulic hot press machine to fabricate composite panel:

a. Design of Hydraulic Hot Press Machine

The hydraulic hot press machine design proposes a relatively simple design that uses a hydraulic jack car, a heating element, and a PID controller temperature to achieve the machine's goal. Before proceeding with the construction of the machine, it is critical to understand the machine's method of operation and ensure that the machine can function as intended. This method may need numerous trials to develop a design, since improvement from one design to the next will be necessary.

b. Material Selection

Leads in material identification and selection. Based on a literature research and past work, materials are identified during the early design phase. At the end of the design phase, materials with specified characteristics are chosen. In the project pricing and materials, the materials chosen were appropriately listed.

c. Simulation

Oversees the use of SolidWorks to simulate a hydraulic hot press machine. Based on material characteristics and measurements, SolidWorks was used to model the hydraulic hot press machine. Assemble the system's components appropriately and check that it works as intended in compliance with the project's objectives.

d. Hydraulic Hot Press Machine Fabrication

Fabrication of a hydraulic hot press machine is the process of creating a prototype based on a preliminary design. Machining, cutting, drilling and welding will all be part of the fabrication process. Fabrication work will necessitate a set of machine handling skills as well as adherence to safety regulations to avoid any mishaps.

e. Hydraulic Hot Press Machine Testing

After completing the fabrication process, a testing method is required to ensure that the hydraulic hot press machine functions effectively and without failure. It's critical to ensure that the machine's frame can withstand the pressure exerted by the hydraulic jack, and that the PID controller function for controlling plate temperature is functioning effectively. The most essential feature is that this machine can produce a high-quality composite material.

1.5 Research Methodology

Several research methodologies had been planned to identify, select, process and analyzed information about this project. This will help the overall process of this project can run smoothly as planned. The project shall be carried out accordingly to this set of methodology that had been planned as following:

a. Literature Review

A survey of literature related to the area of hydraulic hot press machine in composite panel fabrication will be conducted by reviewing existing journal, articles, books, websites, and any online references, and the information gathered will be synthesized into a summary as part of the literature review process. The idea and guidelines from this approach will be used to design and fabricate a hydraulic hot press machine

b. Theoretical Modelling

A hydraulic hot press machine solution will be designed using mathematical modelling and theory drawn from engineering theory and any information from a reference.

c. Virtual 3D Model System Development

A virtual 3D model of hydraulic hot press machine should be constructed using CAE software based on the theoretical parameters and idea obtained from a reference.

d. Virtual Model Performance Assessment

The performance assessment conduct by run a flow simulation analysis using CAE software and the results will be evaluated afterward for validation how well the system work.

e. Physical System Development

Based on the virtual design and functionality assessment, the hydraulic hot press machine for fabricated composite panel prototype shall be fabricated. The fabrication shall be referred to the CAD blueprint drawing. The prototyping involving tasks such as machining, welding, cutting and so forth.

f. Physical Performance Assessment

To evaluate the physical performance of hydraulic hot press machine on pressure delivering onto flat surface plate, temperature control and rate of cooling and heating.

g. Documentation

All the finding from this design project is documented as the Final Year Project thesis.

The research project methodology can be summarized as a flow chart shown in the Figure 1.1.

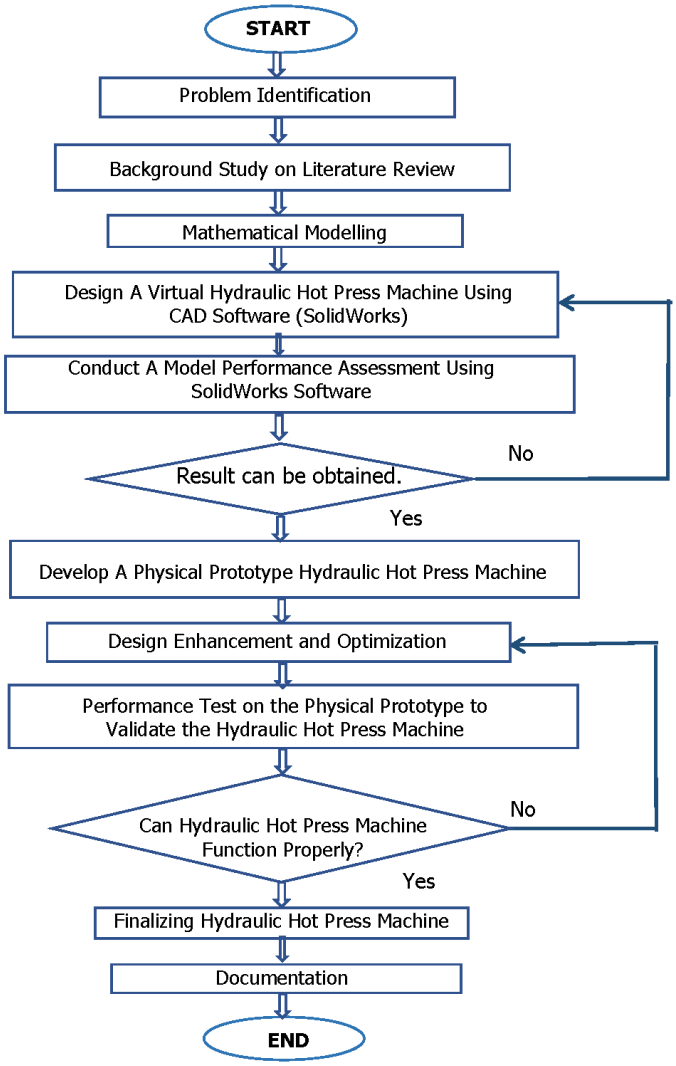

Figure 1.1 : Project Flow Chart

1.6 Thesis Organization

This thesis is organized as follows:

Chapter 1 provided a detailed introduction to this hydraulic hot press machine. This chapter listed the main objectives of this experiment, followed by the methodology, flowchart, scope of work and so on. Other than that, this chapter also explains how this thesis is carried out specifically.

Chapter 2 is a compilation of different literature reviews on the same topic, which is hydraulic press and hydraulic hot press machine. This chapter discussed recent developments and research conducted by researchers from a variety of disciplines, working principles and mathematical equations related to the working principle of hydraulic hot press machine. This chapter also includes summaries of the literature review to highlight the main findings.

Chapter 3 elaborated the project's preliminary design. This chapter also included the theory for mathematical modelling of the machine component. Aside from that, all the design requirements were outlined in this chapter.

Chapter 4 provided the reader with virtual design and development of the project. It is divided into few parts which discussed about the mechanical and control system of marine propulsion experimental devices. Also, it shows the simulation of the project using the computer aided engineering tools. The function and performance of the system are evaluated through the simulations.

Chapter 5 elaborated the results, where result is the performance evaluation and assessment findings obtained from the previous chapters are gathered and compared to be validated and discussed. This section also provided the analysed data for both virtual and theoretical modelling performance of the hydraulic hot press machine.